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Aligning Economic Impact with Environmental Benefits: A Green Strategy Model

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***Abstract*—To achieve lower energy consumption many green strategies (e.g. virtualize applications and consolidate them on shared server machines, or optimize the usage of the private cloud by opening up to external consumers) have been discussed. In practice, however, the major incentive for a company to go green is reducing costs. While green strategies often focus on technical and environmental issues, they hardly address the economic impact that they may bring. If green strategies do not lead to an explicit (and significant) reduction of costs (hence increase in revenues) they are nice but not part of the business strategy of the company. In this paper we propose a green strategy model that provides decision makers with the information needed to decide on whether to take green strategies and eventually how to align them with their business strategies. This model provides a means to codify green strategies in such a way that the link between green strategies, their economic impact and green goals becomes explicit. We applied the model in a case study to codify 132 green actions collected from Dutch data centers. This exercise further confirmed the advantage of using the proposed model and helped us identifying future improvements.**

***Keywords*-Green IT; green strategy; sustainability**

I. Introduction

Over the last decades, the use of Information Technology (IT) has been exploded to nearly everywhere, making our lives and work much more efficient and convenient. Besides the benefits that IT brings us, it also contributes significantly to environmental problems [1]–[4], not only because of the electricity consumed by computers, data centers, networks, and other IT utilities, but also due to the short life cycle of IT hardware. While "going green" has become a global topic in recent years, making IT greener has been attracting tremendous attention from both academia and industry aiming at understanding and reducing the energy consumption of computing systems [5], [6].

Many green actions and strategies have been discussed in the literature and practiced in the industry to achieve the green goal of lower energy consumption. During the life cycle stages of IT, green strategies can be applied in green design (e.g. the move from single-core to dual- and quadcore processors [7]), green manufacturing (e.g. making green PCs using nontoxic materials that consume less electrical power and are easily reassembled [7], produce upgradable equipment [8]), green use (e.g. reducing energy consumption by PCs or enabling power management features [7], print more efficiently by e.g. printing double-sided [9]), and green disposal (e.g. reuse, refurbish, and recycle [7], redeploying IT equipment to other areas of the company, resort to donation as a means of disposal [10]).

From these examples of green strategies, we can see that applying a green strategy to achieve environmental goals is obviously not costless. It requires additional investments, business process changes, and extra efforts from both companies and individuals. Although many of the green strategies would lead to lower energy bills for a company (and thus reduce costs), the tradeoff between the economic gain and investment is often unclear to the decision makers of a company. As a result, green goals are often regarded as a nice optional bonus rather than a must-have target, and the priority of green goals decreases.

To ensure economic benefits while making a sustainable business, there must be an alignment between green goals and organizational/business goals. Only when such an alignment is in place, the decision makers of a company can be motivated to take green actions [11]. In the business domain, the strategy modeling language (SML) [12] has been used to align business model with business goal, business plan, and optimization objectives to ensure business strategies can be optimally realized. To our knowledge, currently there is no systematic approach to describe solutions, actions, or strategies that can produce environmental benefits and enforce the alignment between green strategies and business goals.

To this end, in this paper we propose a green strategy model to codify green actions (or solutions, practices) aiming at achieving environmental goals, and to explicitly link green actions to its economic impact and green goals. This link aids the tradeoff analysis between financial investments and economic benefits. Such tradeoff analysis provides evidence for decision makers to apply green strategies and accommodate business and operational goals to green goals. Moreover, by modeling green strategies in a systematic way, green strategies from multiple companies can be compared, integrated, or generalized to a set of green approaches that can be shared and reused among companies.

The remainder of the paper is structured as follows. Section II explains the design of the green strategy model. Section III introduces a case study that we carried out to codify the green actions of several Dutch data centers using the proposed green strategy model and discusses our experience in using the model and the lessons learned. Section IV concludes the paper.

II. The Design of the Green Strategy Model

The design of our green strategy model was inspired by the definitions collected by the Global Development Research Center (GDSC[1]), which is an independent non-profit think tank carrying initiatives in education, research and practice. Their goal is to contribute to broad-based global development by facilitating the creation and use of knowledge. The GDSC glossary of environmental terms elicited definitions from international organizations (like ISO and the Environmental Protection Agency of the USA). We found two definitions especially relevant to our purposes:

Definition 1. *A* **green strategy** *(aka environmental strategy) is a plan of action intended to accomplish a specific environmental goal.*

Definition 2. *A* **green goal** *(aka environmental goal) is an objective that an organization sets itself to achieve, and which is quantified where practical.*

The first definition breaks down a strategy into two components: a plan of actions and a specific environmental goal the actions should help achieving. Moreover, the second definition implies that whenever applicable we should be able to quantify the extent to which an environmental goal is achieved. This calls, in our opinion, for the association of metrics (either qualitative or quantitative) that measure the contribution of each action to the achievement of the goal.

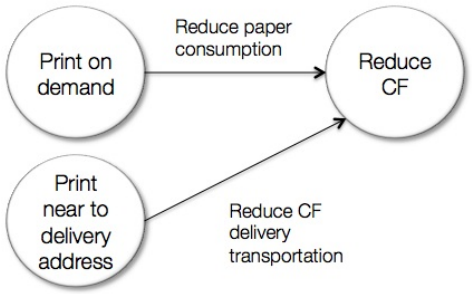

Figure 1. Example 1: A Green Strategy for Electronic Bookstores

Putting the above elements together, we designed the first version of a green strategy as graphically illustrated by the example in Figure 1. The example has been extracted from the electronic bookstore domain. It represents a strategy aiming at reducing the carbon footprint (CF) of printing books. The strategy includes two actions: the first action *Print on demand* refers to printing books only after customers order them. This action makes the business more sustainable by reducing the costs of storing books in large quantities before customers order them. While this effect is not "green per se", i.e. it does have an indirect positive impact on the total CF by reducing paper consumption to the minimum (i.e. exactly the amount of books that are actually ordered by customers). The second action *Print near to delivery address* is to physically print the ordered books in a store as near as possible to the address of the customer. This allows to shorten the delivery distance, hence reducing the CF of transportation.

We developed a number of examples (from both theory and practice) to challenge our first model of green strategy. In doing that, we have identified the following weaknesses.

1) Each action can have one or more effects that help achieving the environmental goal. In order to select the best actions to put in place in a certain organization we must make each effect explicit. In doing that we can understand further what we need to measure to monitor the progress toward achieving the green goal. For instance, in the example of Figure 1 the action effects (added on the associated arrows) identify that by monitoring paper consumption and transportation distances, respectively, we can draw the trend toward reducing the total CF.
2) While action effects are typically technical or environmental in nature, they do not explain the economic impact that they have. We had various discussions with companies actively involved in green ICT and/or in decreasing their CF, and all explained that the major incentive for them to go green is to reduce costs. Hence, if green strategies do not lead to an explicit (and significant) reduction of costs (hence increase in revenues) they are (again) nice but not part of the business strategy of the organization. In periods of economic crisis, they are the first to be forgotten, or neglected.

To challenge our first model in aligning green strategies and business strategies, we associated each action effect with its (potential) economic impact. This resulted in the revised green strategy model illustrated in Figure 2. A green goal *is realized by* a number of green actions, and a green action can achieve a number of green goals. Each green action has a description to explain what the green action means. A green action *leads to* at least one action effect, which *causes* at least one economic impact. A green action *belongs to* one sub-category, which is a sub-set of a category. While the green goal represents ecologic impact of the strategy as a whole, the action effects detail the ecologic impact of each action individually.

[1] www.gdrc.org

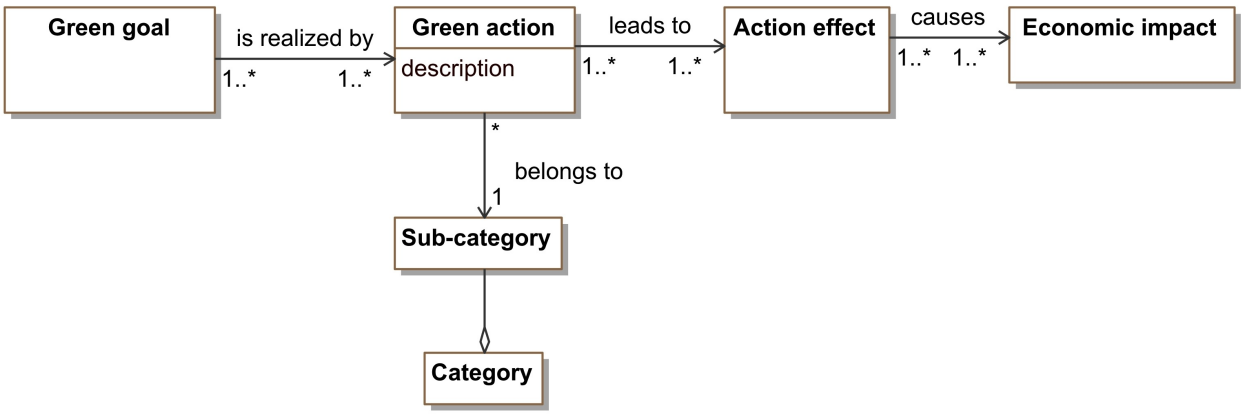

Figure 2. The Green Strategy Model

III. A Case Study - Codify the Green Actions of Dutch Data Centers Using the Proposed Green Strategy Model

After the design of the green strategy model, we planned to challenge the model to find out its suitability in making explicit and aligning the economic impact of green actions and the corresponding environmental benefits. One way to challenge the model is to codify green strategies that have been used or proposed in industry. By doing so, we would be able to assess the added value and limitations when using our model to codify the green strategies.

To challenge the model we selected an industrial case where 132 green actions were documented by the MJA (Meerjarenafspraaken meaning long-term agreements) [13]. The MJA is a voluntary agreement between the Dutch government and the largest energy consumers in the Netherlands, these being both large industries (e.g. banks and telecom providers) and higher education institutes (e.g. universities). This agreement is brought to life in order to improve the energy efficiency of products, services and processes resulting in a reduction of fossil fuel usage. It relates to activities within businesses and sustainable energy. For more than 15 years the MJA has been in place and has proven to be a good measure in realizing improvements in energy efficiency.

In the case study, we have been provided with a spreadsheet of the 132 green actions gathered by multiple data centers as part of MJA agreements decided by the Funding Agency of the Dutch Ministry of Economic Affairs, Agriculture and Innovation[2]. The spreadsheet of green actions has been created by domain experts, who are responsible for designing and managing data centers. Each action is described in terms of 30 different fields, including e.g. *branch, type, short descriptions, long descriptions*. These actions are meant to lower and optimize the energy consumption needed to run a data center in terms of deployed applications, deployed hardware, cooling, lighting, redundancy on energy supply, space organization, design of the datacenter, network capacity and so on.

One of the objectives of creating such a spreadsheet was to collect green actions of each data center, and then share and communicate with other data centers. Despite that a spreadsheet with pre-defined fields is used to document green actions, different experts describe the green actions in different manners, in terms of the level of detail and abstraction, as well as the assumptions made on the background knowledge of readers. As a result, the decision makers of data centers could neither completely understand the green actions nor estimate the investment needed and the economic benefits that could be brought by each green action. As a result, the usefulness of such a shared spreadsheet is lost.

In the following, we introduce the steps we took to codify the green actions provided to us, present an example of a codified green action, and discuss the lessons we learned from the case study.

A. Case Study Execution

As input to our case study we received a spreadsheet containing 132 actions described by 30 fields. This spreadsheet was written in Dutch, and contained actions and best practices originated by organizations participating in the MJA agreement, and meant to optimize energy consumption and management of data centers.

To codify the green actions according to our proposed model we have taken the following four steps:

1) **Translate the document from Dutch to English.** Translating in English was a necessary step to be able to reflect and share the findings of this work. We consider English language universally understood in the community and industry, and therefore more suitable to share opinion and information with people all around the world. The translation has been first performed by

[2]www.agentschap.nl

Google Translate, and then refined by a native Dutch speaker in order to spot and remove grammar errors and ambiguities.

2) **Identify the fields that are most relevant for the model.**
   In the initial MJA spreadsheet provided to us each green action is described by 30 fields. However, not all fields are directly relevant to make green actions reusable. After studying the spreadsheet, we excluded the fields that are considered irrelevant. For instance, some of the fields are filled in with company specific codes and no additional documentation is provided for understanding the codes; some of the fields are left empty; and some of the fields are meant for administrative purposes (e.g. field *old measure code* has been used to track back to historically used measurement).
   As a result, we found only 7 out of 30 fields useful for the codification. Among these 7 fields, 3 (*Sub-category, short description, long description*) have been mainly used to the mapping, while the other 4 (*EIA-code, VAMIL, Branch, and type*) helped us to understand the context and the meaning of a green action.
3) **Map the identified fields to the elements of the proposed model.**

Table I
MAP THE MJA SPREADSHEET TO THE GREEN STRATEGY MODEL

Green strategy model element	MJA spreadsheet field
Green Goal	Sub-category
Green Action Name	Short description
Green Action Description	Long description
Action Effect	Long description, EIA-code, VAMIL
Economic impact	Long description
SubCategory	Branch and Type
Category	"green IT" or "greening of IT" based on our own interpretation

When studying the MJA spreadsheet, we noticed that there is a common pattern between the spreadsheet and the green strategy model. Such pattern is presented in Table I, which we used to map the fields from the MJA spreadsheet to the elements of the green strategy model. The *sub-category* field of the MJA spreadsheet shows what the general achievements of green actions are and is consequently mapped to the *green goal* in the model. The *short and long description* fields of the MJA spreadsheet are the most descriptive ones. They are meant to describe in detail the green actions, from which we may derive *green action name* and *green action description*.
In addition, the *long description* often includes information about environmental effects and sometimes also about economic impacts. By interpreting the information and making assumptions, we were able to elicit *action effects* and *economic impacts* (even if not explicitly stated).
The fields *VAMIL*[3] and *EIA-code*[4] show the opportunities for tax reductions by applying a green action. When the values of these fields are present, we derived the *action effect* as "eligible for tax reduction" and *economic impact* as "savings due to tax reduction".
The fields *branch* and *type* express categories that are commonly used by data centers (e.g. cooling, management, design), which is naturally mapped to the *sub-category* element of our model.
The element *category* has been filled by means of our own interpretation, so that we can use the distinction between *greening of IT* (i.e. the optimal use of IT to minimize environmental impact) and *greening by IT* (i.e. minimizing the environmental impact by using IT resources), two main roles that IT plays in achieving environmental goals [2], [14], [15].

4) **Codify the green actions.**
   The previous three steps are meant to prepare the green actions provided as input to the case study. In this fourth step we carried out the actual codification of the 132 green actions using our proposed model. To do so, we first studied the identified 7 fields of each green action; then elicited information relevant to each element of the green strategy model based on Table I; and finally filled in each element with the elicited information, our assumptions, and information that we concluded based on our interpretation and reasoning.

B. An Example of a Codified Green Action

In this section we present an example of the codification of green actions (the last step of the approach). A green action taken from the MJA spreadsheet is shown in Table II. As explained in our approach, we used a common pattern (see Table I) to codify the green actions. The *green action name* and the *green action description* are taken from the short and long descriptions, respectively. The contents of these two fields are in our opinion clear enough.

In this example, *action effect* and *economic impact* were the most difficult ones to codify because there is almost no explicit description of the effects that may occur with this green action, and economic impact is fully missing.

[3]VAMIL is a scheme, promoted by the Funding Agency of the Dutch Ministry of Economic Affairs, Agriculture and Innovation. It grants tax reductions to companies for their investment in creating environmental optimizations.

[4]EIA (Energy Investment Allowance) is a program promoted by the Funding Agency of the Dutch Ministry of Economic Affairs, Agriculture and Innovation. It is meant for companies that invest in sustainable energy or in assets that save a certain amount of energy. This scheme offers entrepreneurs a direct financial advantage, because they can deduct an extra amount of 41,5% of the investment costs of these corporate assets from their profits.

Nevertheless, we tried to understand the meaning of the green action and make some assumptions. The first sentence from the *long description* says "This UPS system does not need batteries attached." From this sentence we deduced two action effects and their corresponding economic impact. One effect is that there is no need to buy batteries, hence reducing operational costs for keeping the system running. Another effect is that no battery disposal and recycle is needed and hence saving costs.

Table II
AN EXAMPLE OF A GREEN ACTION TAKEN FROM THE MJA SPREADSHEET

MJA spreadsheet field	**Contents**
Sub-Category	*Energy saving projects in utilities and buildings*
Short Description	*Battery-free UPS system*
Long Description	*This UPS system does not need batteries attached. As compared to other battery systems, it can work with a wider temperature range.*
EIA-code	*320000/420000*
VAMIL	*none*
Branch	*ICT/datacenter*
Type	*emergency power supply*

Table III
AN EXAMPLE OF A CODIFIED GREEN ACTION

Model elements	**Contents**
Green Goal	*Energy saving projects in utilities and buildings*
Green Action Name	*Battery-free UPS system*
Green Action Description	*This UPS system does not need batteries attached. As compared to other battery systems, it can work with a wider temperature range.*
Action Effect	*1. No need to buy batteries.* *2. No battery disposal and recycle is needed and therefore it is environmentally friendly.* *3. Since the system can work with a wider temperature range, less cooling is needed.* *4. Eligible for EIA 320000/420000.*
Economic impact	*1. Save operational costs for purchasing batteries.* *2. Save costs for disposal and recycling batteries.* *3. Save energy costs.* *4. Save operational costs due to tax reduction*
Category	*Greening of IT*
SubCategory	*ICT/datacenter, emergency power supply*

The second sentence says *"As compared to other battery systems, it can work with a wider temperature range."* We interpreted that free-battery UPS systems can tolerate higher temperature as compared to other battery systems, and therefore less cooling is needed. Therefore, we codified the third *action effect* as "less cooling is needed". From this effect we assume that less cooling means either less cooling devices are needed or cooling devices may work less. In both cases less energy would be consumed and therefore we codified the *economic impact* as "Save energy costs."

Finally, the last *action effect* we elicited comes from the *EIA-code*. Because of the Energy Investment Allowance program[5], some energy investment may eligible for tax reduction. Therefore we codified the third *action effect* as "Eligible for EIA 320000/420000" which obviously leads to an *economic impact* "Savings costs due to tax reduction".

As for the *category*, we consider this measure being a "Green of IT" action, because it creates benefit by renewing equipment in IT, but there is no direct benefit for other sectors. *Branch* and *Type* in the MJA spreadsheet have been directly codified as Sub-category.

In this way we were able to codify the green action using the green strategy model, which is presented in Table III.

C. Findings

The goal of our case study has been to challenge our green strategy model and find out its suitability in making explicit and aligning the economic impact of each green action and the corresponding environmental benefits. While none of the 132 MJA green actions did explicitly describe this alignment, during the codification we either had to elicit economic impact and environmental benefits embedded in the action description and then make their alignment explicit, or draw assumptions sometimes grounded in theory. Of course the latter case will need to be validated by interviewing domain experts who own the MJA green actions.

In general, we have been able to represent all relevant fields in the original MJA spreadsheet with our model. This gives us confidence on its suitability in codifying green strategies. The next step, however, would be to go back to the companies, or involve other ones, to check if our way to align economic impact and environmental benefits is effective and sufficient to decide on the best fitting strategy.

Further, the case study allowed us to collect the following additional observations on the codification as well as a list of issues that should lead to further improvements to our strategy model.

- **Advantages of codification:**
  - **The understandability of green actions is improved.**
    As we mentioned earlier, the green actions provided to us were documented by domain experts who made assumptions that readers having sufficient background knowledge to understand. However, when shared with other data centers or presented to a third party (e.g. our university for research purposes), the documented green actions are often not completely understandable and less usable. By codifying the

[5]www.solarthermalworld.org/node/709

green actions, they are easier to be shared and communicated since assumptions and domain knowledge embedded in the descriptions become explicit. For instance, in our example discussed in Section III-B the consequences of using a battery-free UPS system are less clear to the reader before codification. Only after codification it is clear that from environmental perspective it would use less energy for cooling (lower carbon footprint) and it avoids disposal and recycling of batteries (less e-waste and less pollution to the environment), and from economic perspective it saves costs for energy consumption and saves costs for disposal and recycling. Knowing these consequences is essential for companies to understand and select the green action.

- **Searching and selecting green actions for specific purposes becomes easier.**
  Very often, a company would search for green actions to achieve certain environmental goals, which is also the purpose of sharing green actions among multiple data centers under MJA agreement. When action effects and economical impacts are explicit, they can be used as criteria for companies to search for green actions that fulfill their business requirement. Further, explicit action effects and economical impacts may aid companies to justify and reason about the selection of certain green actions.
- **The completeness of the documentation of green actions is improved.**
  The model encourages the author of a green action to document and, most importantly, to think about the environmental effects and economic impact that the green action may bring. In the future, when the green strategy model is commonly used for documenting green actions, the authors are guided with what type of critical information to provided. As a result, the chance that the documentation of green actions is complete is much higher.

- **Issues for further improvement:**
  - **Dependences between green actions should be modeled.**
    When codifying the green actions, we observed that some green actions are dependent or related to each other. For instance, one green action is to use adiabatic cooling, meaning that "as a complement to the direct free cooling we can evaporate water into the airflow to remove the heat in the air". Another green action is described as "Moistening and drying air are expensive and energy intensive. Use equipment that operates between 20% and 80% of relative humidity." The former action results in high humidity of the air; and the latter action proposes to use devices that may tolerate wider ranges of humidity so that no extra efforts are needed to moisten or dry air. Obviously, the latter action provides a solution for the problem that the former action introduces. If such relation is explicitly modeled, it is easier to justify the economic impact of both green actions as a whole.
  - **Differentiation between positive and negative impacts should be supported.**
    In the case study, we observed that each green action can have multiple economic impacts, which may be positive (i.e. contributing to reduce costs and increase benefits) and/or negative (i.e. require investments to put the actions in place). Currently, both of the two types of economic impacts are codified by one element (i.e. economic impact) without the discrimination of positive and negative effect. To assess the ROI of a strategy and align it to the organization business objectives is of course necessary to gain clear understanding of both positive and negative economic impacts. Therefore, in our opinion the discrimination of positive and negative impacts should be supported by the model.
  - **References to the application of green actions should be included.**
    We noticed in the MJA spreadsheet that sometimes reference documentation, a case of study or examples are given to show the application or usage of a green action. In our opinion, the information about the practice of a green action is very relevant to give the reader an instrument to get better understanding on a green action, and therefore, should be supported by the model.

IV. Conclusions

To reduce energy costs and contribute to global environmental goals, organizations consider green strategies increasingly often. Sometimes they even add them as part of their organizational strategies. However, experience shows that if green strategies are not in line with business- and organization strategies they are easily neglected, or withdrawn in times of crisis.

To aid organizations in the selection of green strategies and aligning them to their business strategies, in this paper we propose a green strategy model that codifies green strategies in such a way that the link between green goals, action effects, and economic impacts becomes explicit.

In the discussed MJA case study we observed that codifying green actions do help in identifying economic impact and environmental effects, improve understandability, searchability, and encourage the authors to provide information that is critical for decision making. In addition to these advantages, we also observed that *cross-dependencies* between actions, and the differentiation between *positive-* and *negative* economic impact would be relevant but are not supported yet by our model.

The ultimate goal of our research is to establish a green software knowledge base, which shares green metrics, policies, and best practices. This knowledge base will enable researchers and practitioners to exchange knowledge about green software accumulated from academia and industry. The work reported in this paper serves as foundation for the design and creation of such a knowledge base. We are currently working on eliciting metrics from case studies, and extend our model to relate action effects and economic impacts with metrics and key ecologic indicators that quantify/qualify the benefits of green actions, and ultimately the effectiveness of green strategies.

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